High Data Rate Downlink Transmitters for Earth Observation Missions

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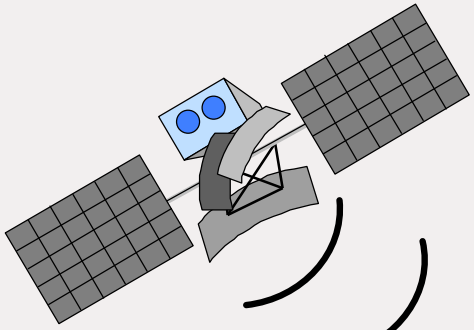
Contents:

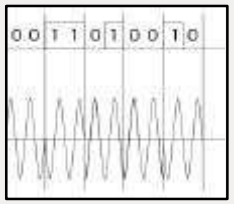
- Tesat‘s X-band Dowlink Transmitters and Subsystems
- Benefits and Limits of QPSK Transmission Scheme
- Outlook to Future Transmission Standards (TCM 8PSK)

X-Band Downlink Subsystem (State of the Art)

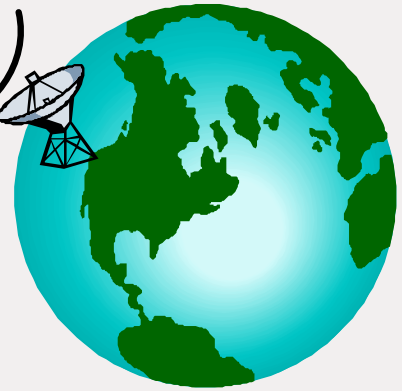


Earth Observation Satellite Acquires Data,
e.g. Radar, Scientific, Weather Data
~ 300 Gbit Data Memory on Board

Downlink Data Transmission
on RF-Carrier in X-Band
7.2 - 7.8 GHz and 8.0 - 8.4 GHz (ITU)

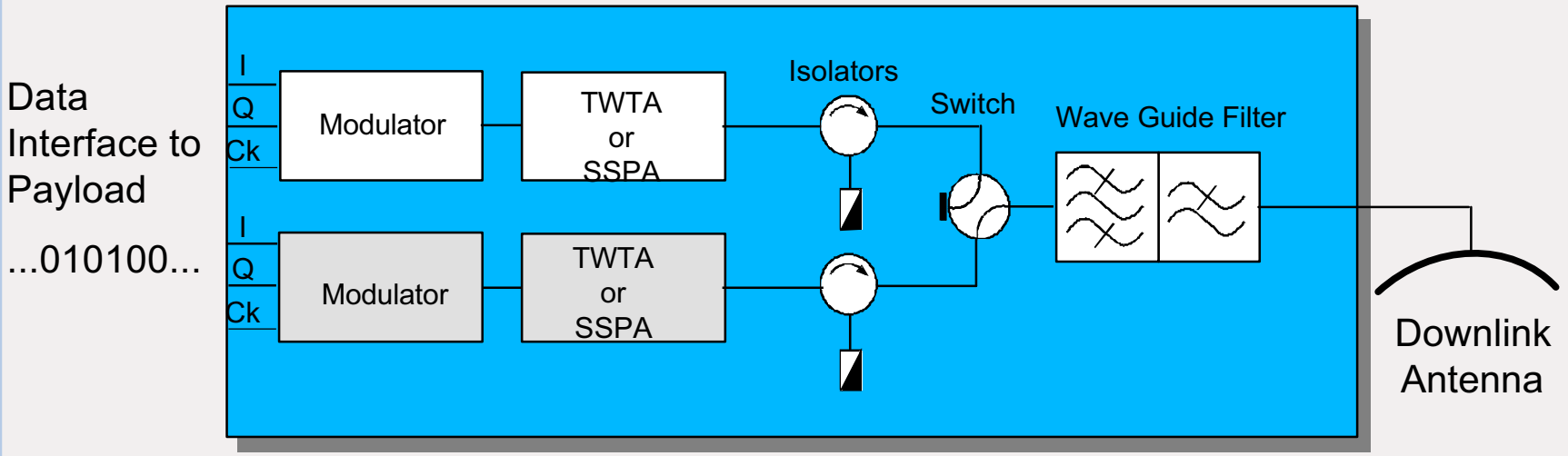


Digital Modulation of Carrier
(Hard Keyed QPSK)



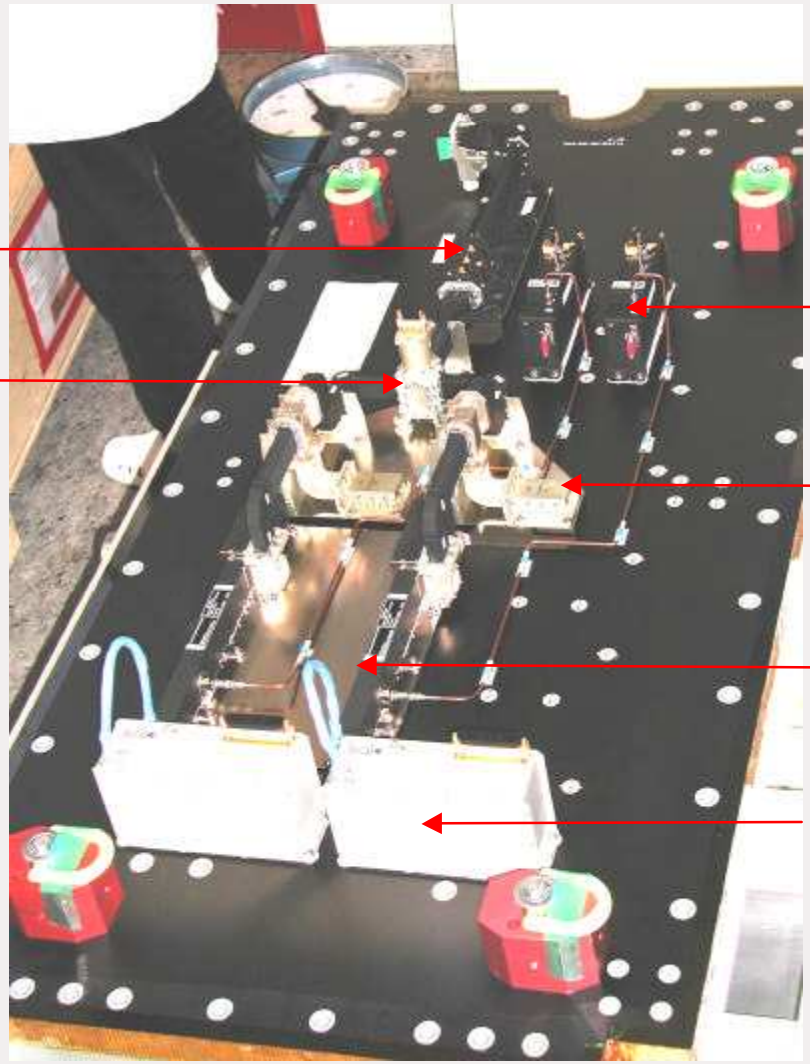
Data Rates up to 300 Mbps Currently Required due of
Short Visibility of LEO Satellites (10 - 20 min)

X-Band Downlink Subsystems by Tesat Spacecom



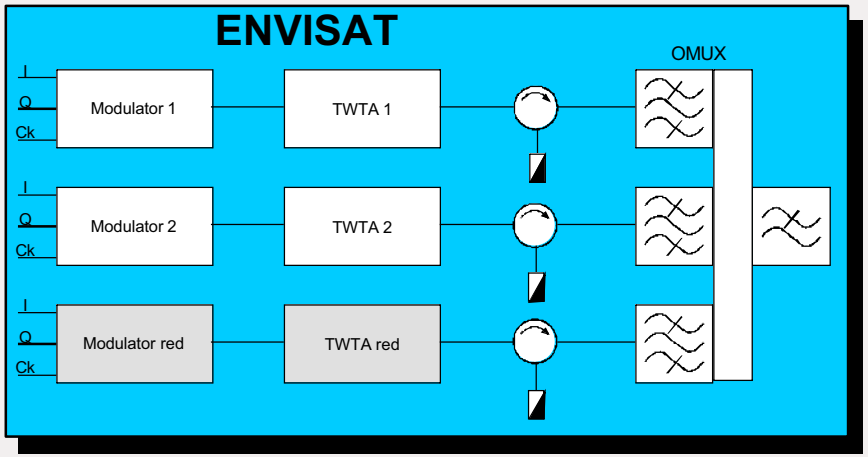
Frequency Range	8.025 GHz .... 8.4 GHz
Data Rate Capability	Max. 500 Mbps in X-Band
RF Output Power	4 W .... 120 W
Subsystems Delivered	20

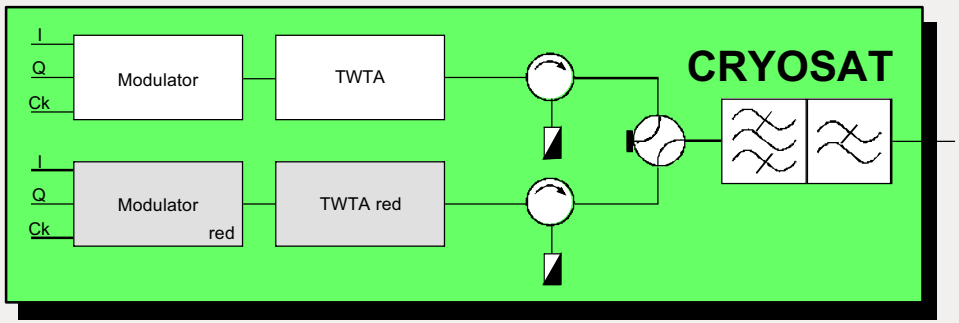
X-Band Subsystem for TerraSAR

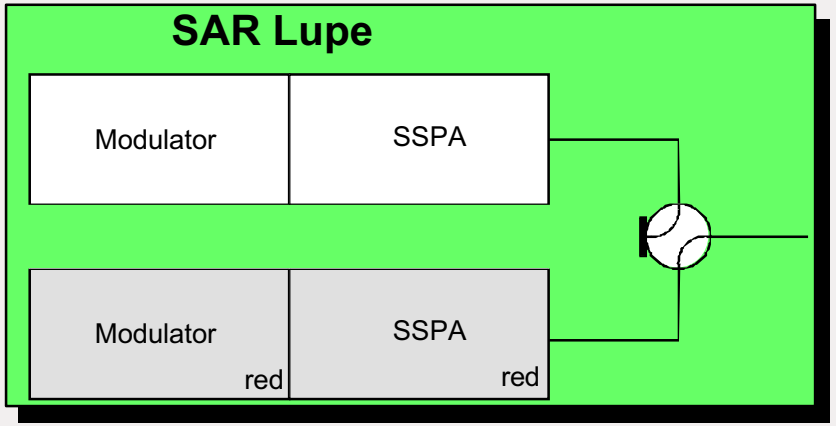


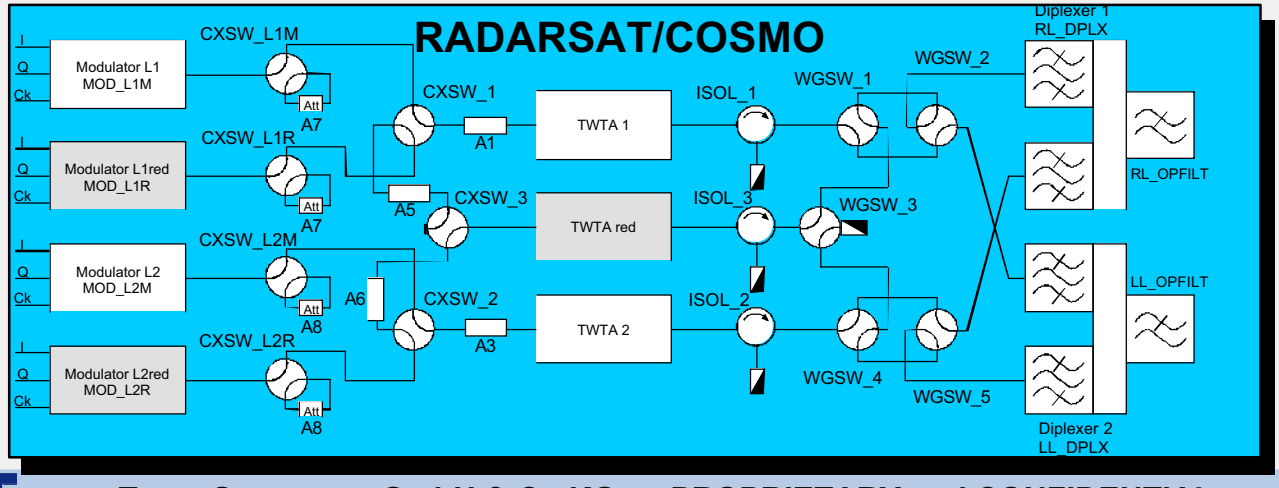
High Data Rate Downlink Transmitters for EO Missions

Tesat High Speed Telemetry Transponders - Block Diagrams



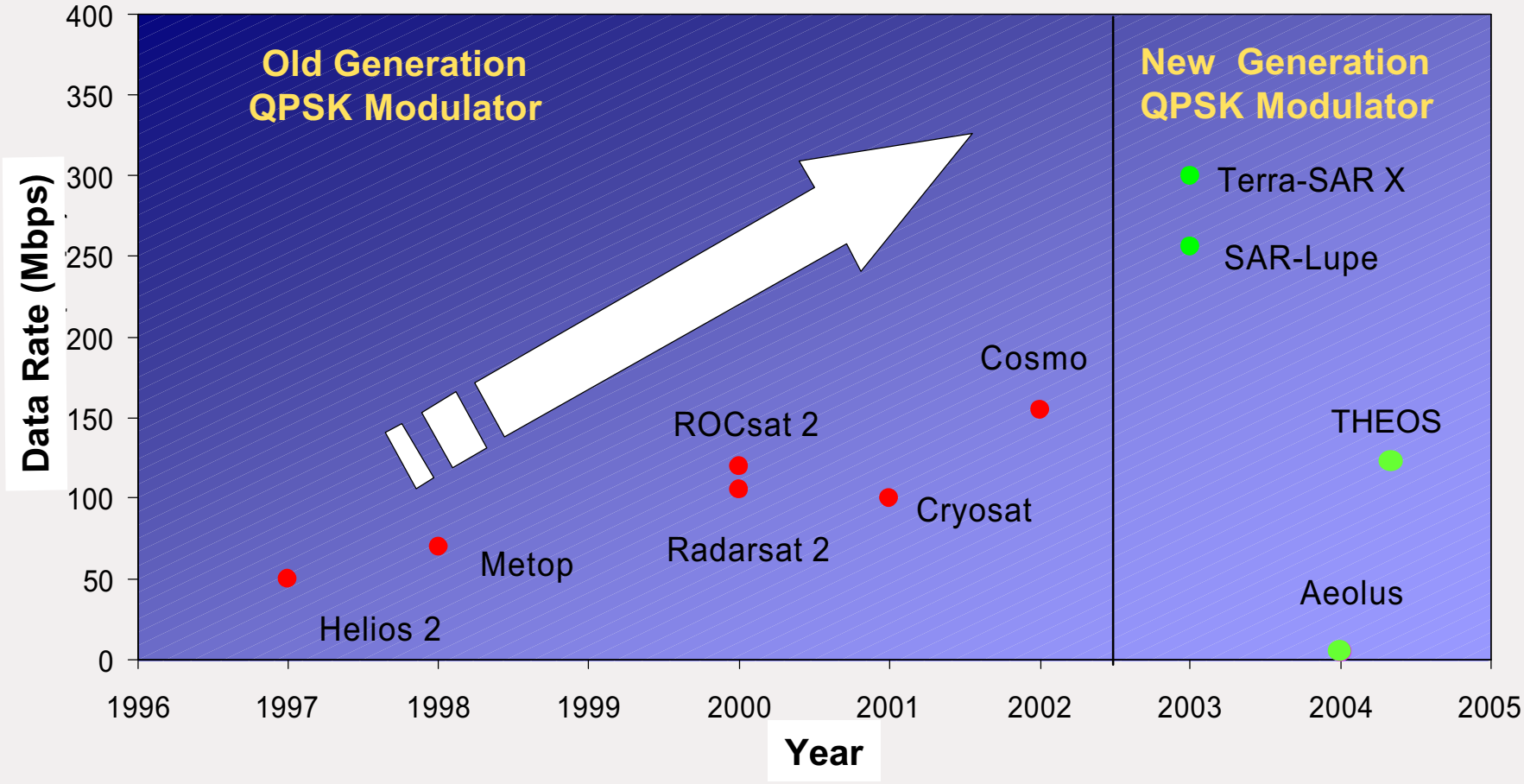




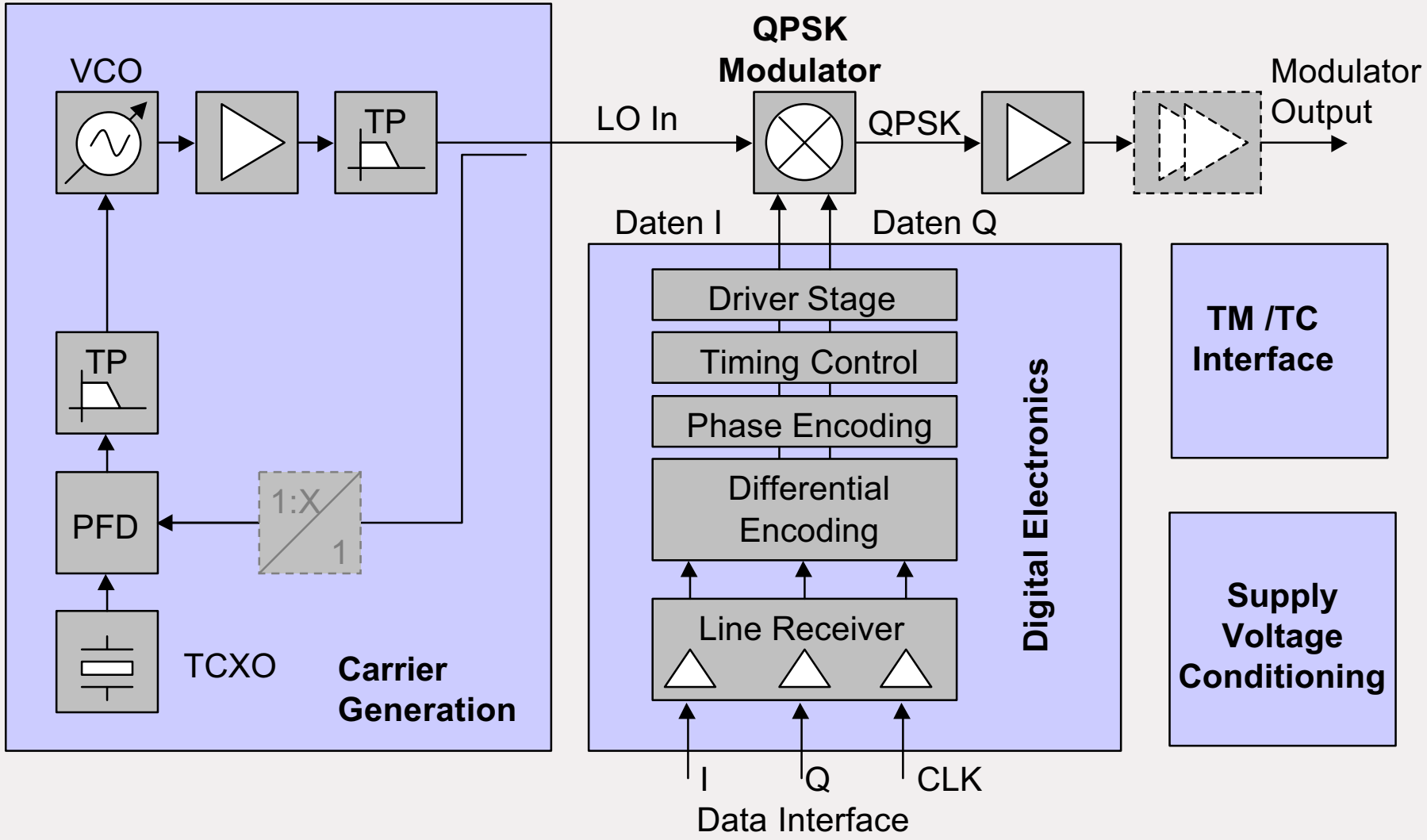


High Data Rate Downlink Transmitters for EO Missions

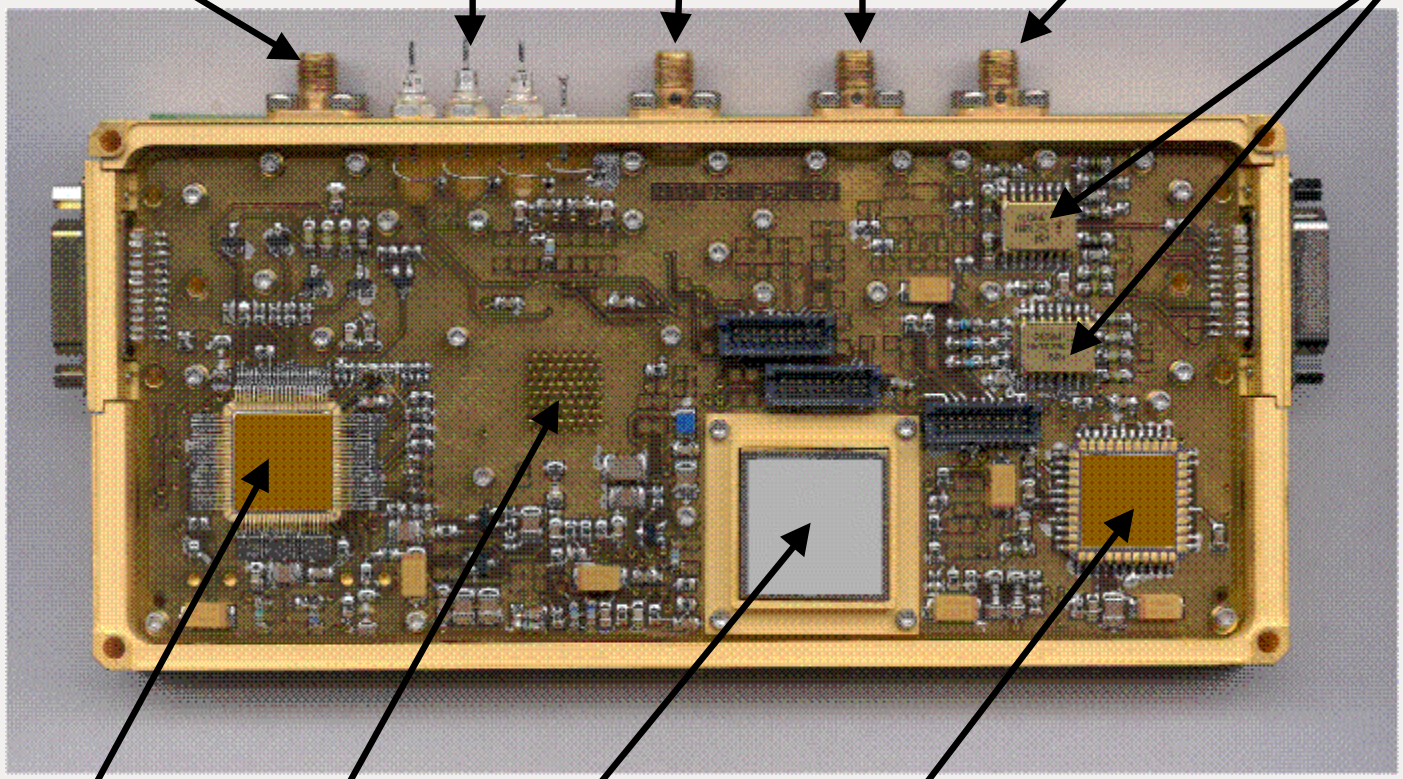
X-Band Downlink Data Rates vs. Time
Flight Programs



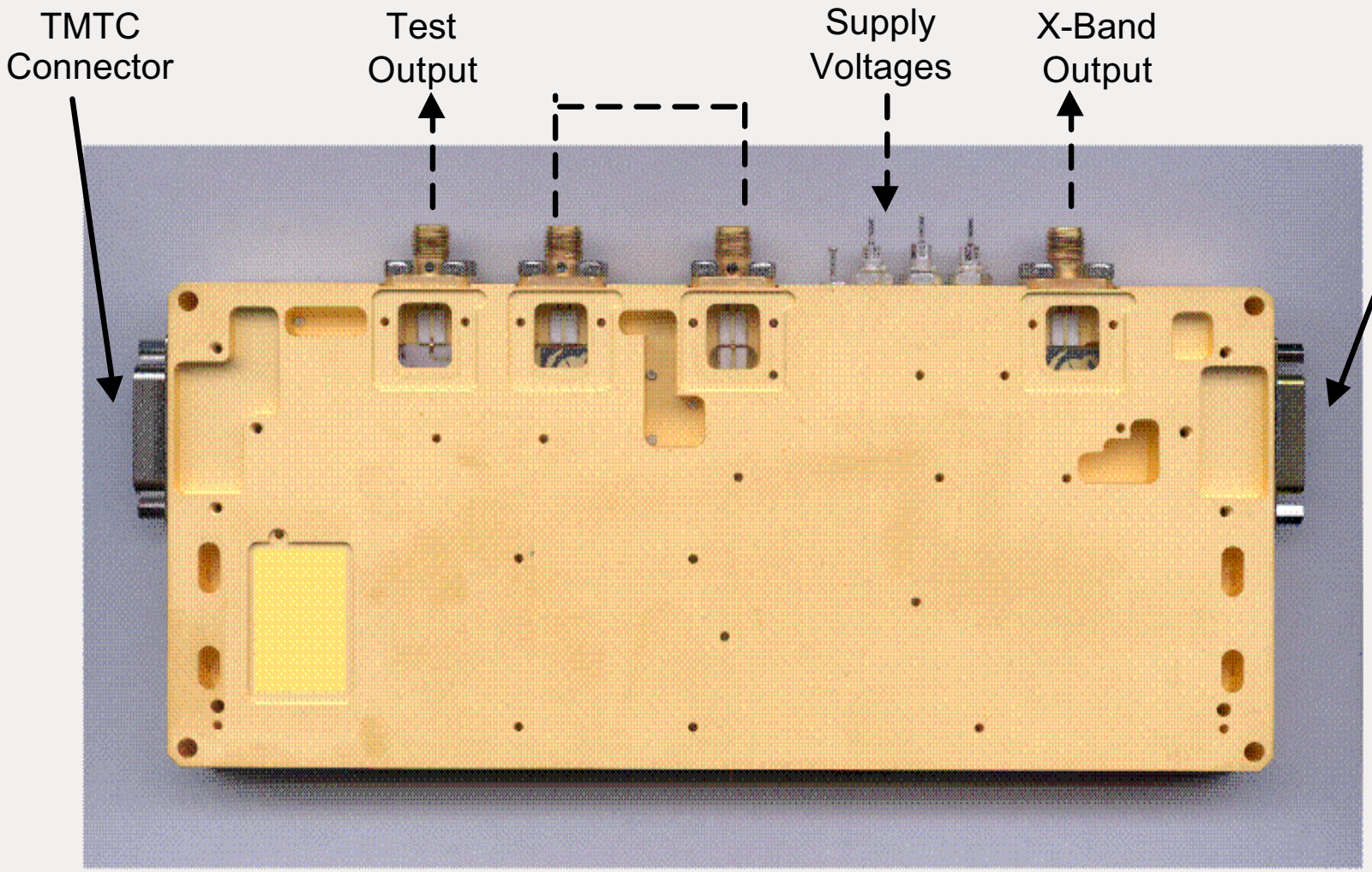
Direct X-Band QPSK Modulator - Block Diagram



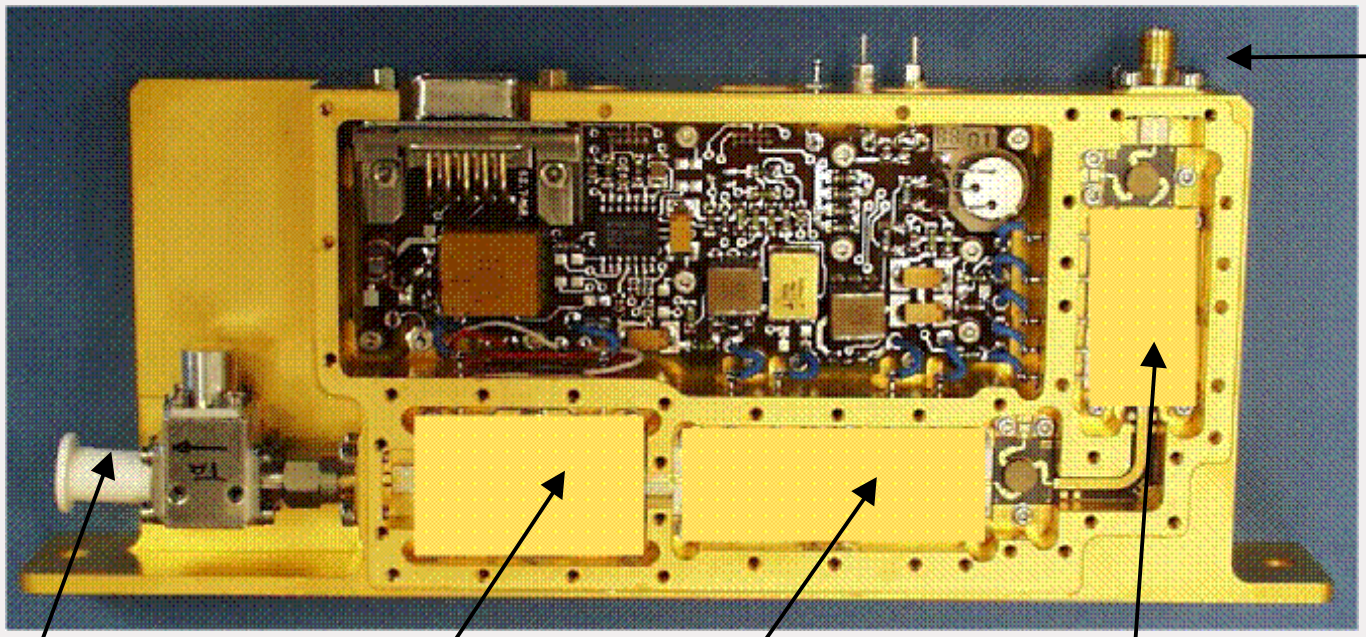
New Generation X-Band QPSK Modulator



New Generation X-Band QPSK Modulator - Housing



Solid State Power Amplifier (SSPA)

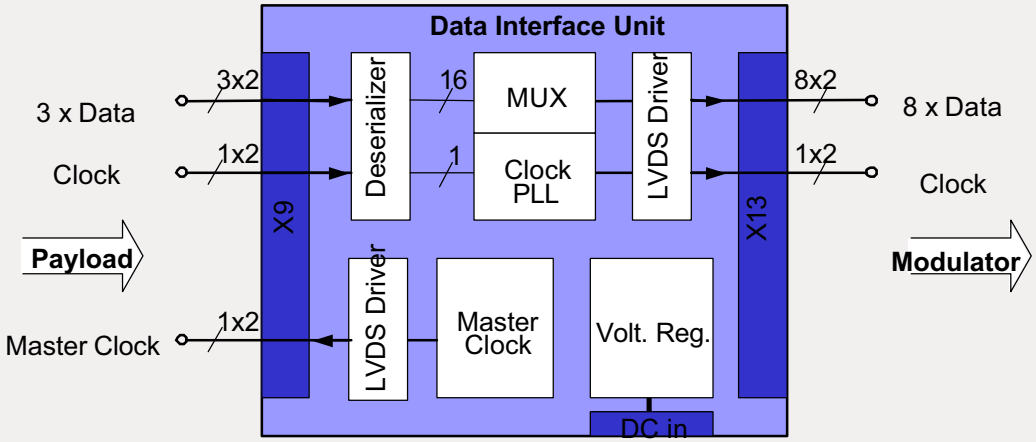


Frequency Range	7.5...8.4 GHz	3rd Order Intermod	17 dBc
Gain	34 dB	Efficiency	30%
Output Power Classes	6 W , 20 W	Mass	350 g

Data Interface Unit

User Specific Data Interface:

- Mux/Demux Functions
- Framing/Encoding Functions
- Encryption Functions
- Clock Generation
- Logic Level Adaption



Example: Deserialiser

Realized Using High Speed FPGA

Data Throughput > 1 Gbps

Housing Compatible to Modulator

X-Band Transmitter (XTRA-6 with Interface Unit)

Interface Unit

Modulator Section

Power Supply

Power Amplifier Unit

Dimensions	197x105x74 mm³
Mass	1100 g
Power Cons.	30 W

Performance Summary

Excellent Performance

⇨ Data Rate Capability	500 Mbps in X-Band	
⇨ Low Phase Noise	1° rms (10kHz ... 10 MHz)	
⇨ High Modulation Accuracy	0,5 dB_{pp} and 4°$_{pp}$	
⇨ RF Output Power Classes	6 W, 20 W,120 W	
⇨ Small Dimensions	197 x 89 x 74 mm^3	(XTRA-6)
⇨ Low Mass	1.1 kg	(XTRA-6)
⇨ Low Power Consumption	30 W	(XTRA-6)

High Flexibility

- ⇨ In Orbit Adjustable Carrier Frequency (8.025 - 8.4 GHz in 5 MHz Steps)
- ⇨ Data Rates 0 - 500 Mbps, Parallel and Serial Data Interfaces (LVDS & ECL)
- ⇨ Arbitray QPSK Phase Mapping and Coding (OQPSK, D-QPSK)

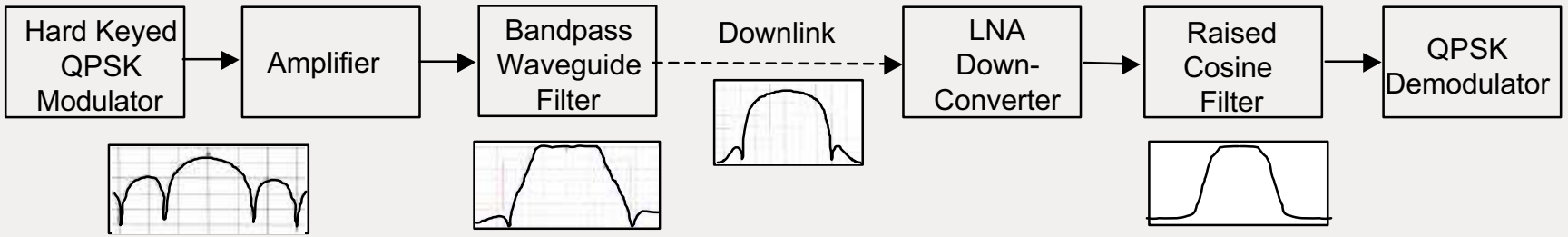
Mature Design

- ⇨ Fully Space Qualified Technology
- ⇨ 4 FMs Delivered, Contracts for Further 14 FM Modulators

Characteristics of QPSK Transmission Scheme

Benefits of QPSK Transmission Scheme

- ⇨ High Spectral Efficiency (as compared to BPSK)
- ⇨ Allows Low Eb/No (as compared to 8PSK)
- ⇨ Highly Efficient On-Board Modulators Available
- ⇨ Ground Station Equipment Available
- ⇨ Excellent BER Performance with Hard Keyed QPSK for Non-Linear Channel (only 1 dB Degradation at BER=1E-6 w.r.t. Theoretical Limit)



Limitations of QPSK Transmission Scheme

- ⇨ Data Rate Limited to < 500 Mbps in X-Band

Future Transmission Standards

ITU Regulated Frequency Band for Earth Observation:

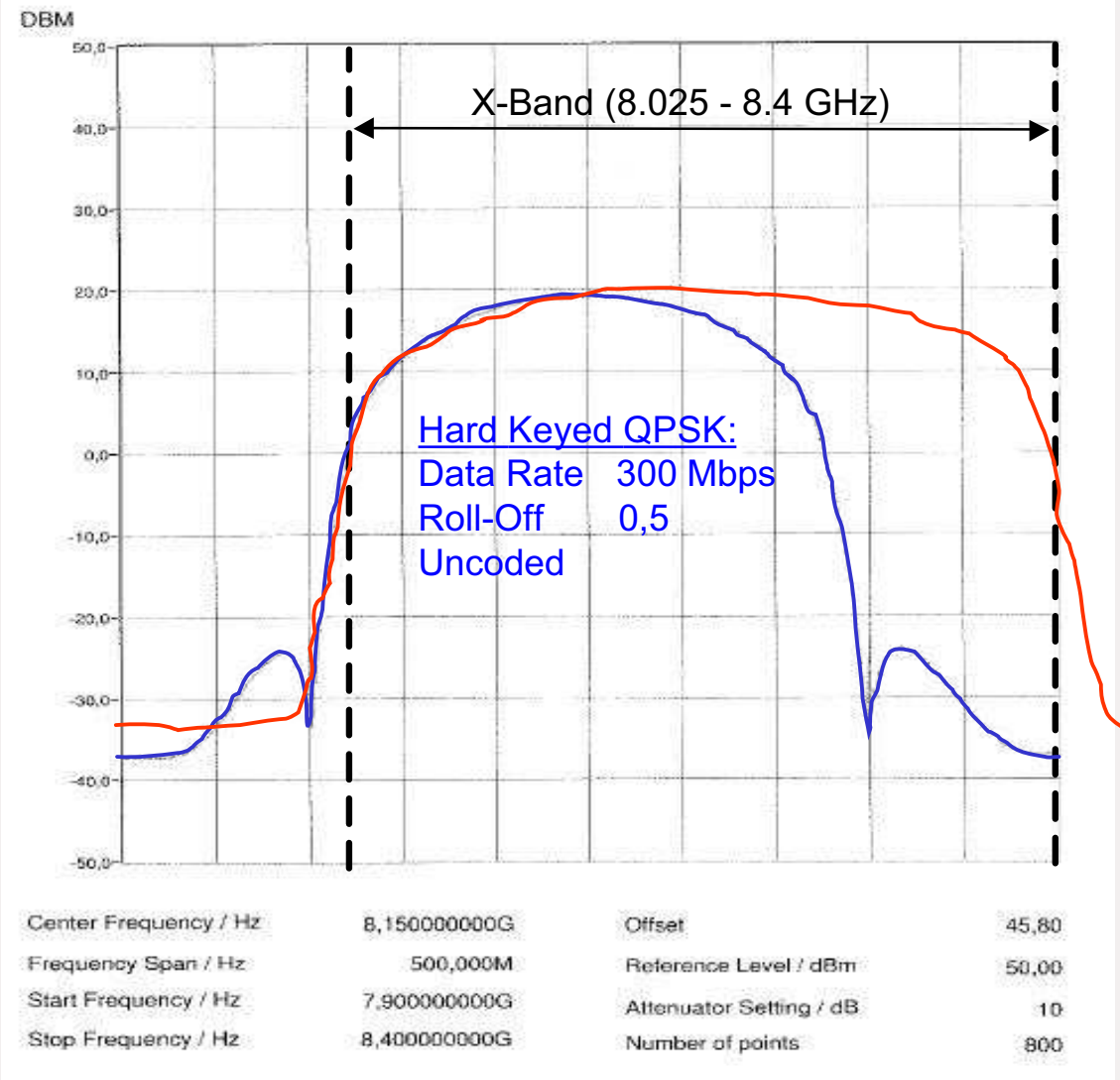
X-Band 8.025 GHz ... 8.400 GHz, BW= 375 MHz

Ka-Band 25.5 GHz ... 27 GHz, BW= 1.5 GHz

Modulation Scheme	Coding Scheme	Occupied Bandwidth for 600 Mbps (@3dB)	Eb/No for BER=10E-6
Filtered QPSK, r=0.35	none	405 MHz	11 dB
Filtered QPSK, r=0.35	RS + Convolutional 3/4	607 MHz	3.7 dB
Filtered TCM 8PSK, r=0.35	RS + Convolutional 2.5/3	321 MHz	7.1 dB

CCSDS recommendation and ESCC-E50 standard call for TCM 8PSK Modulation for high data rate downlinks and on the long term expansion to Ka-band.

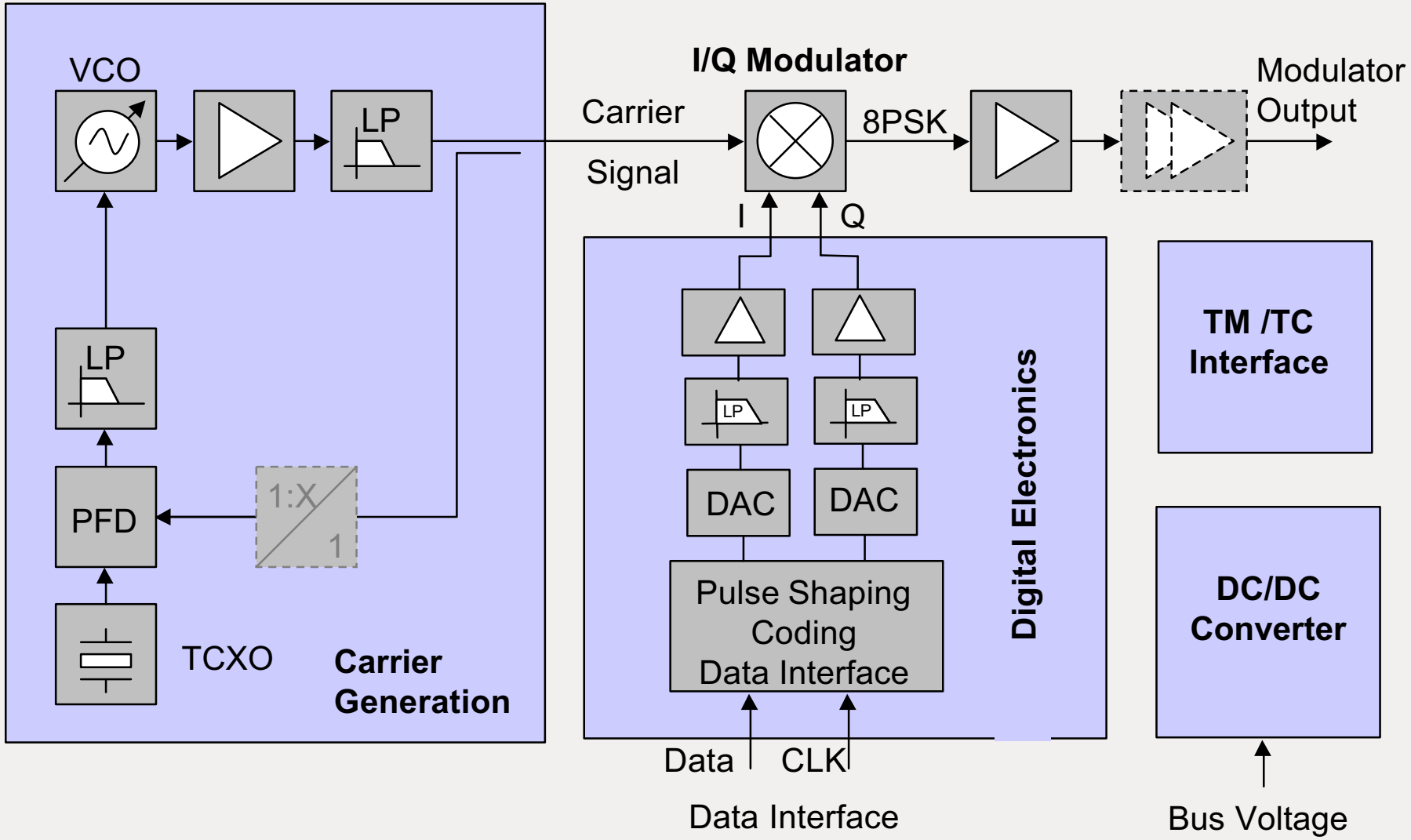
Band Limited Hard Keyed QPSK and 8PSK Signals



Hard Keyed QPSK:
Data Rate 450 Mbps
Roll-Off 0,35
Uncoded

Hard Keyed 8PSK:
Data Rate 600 Mbps
Roll-Off 0,35
Coded RS&CV

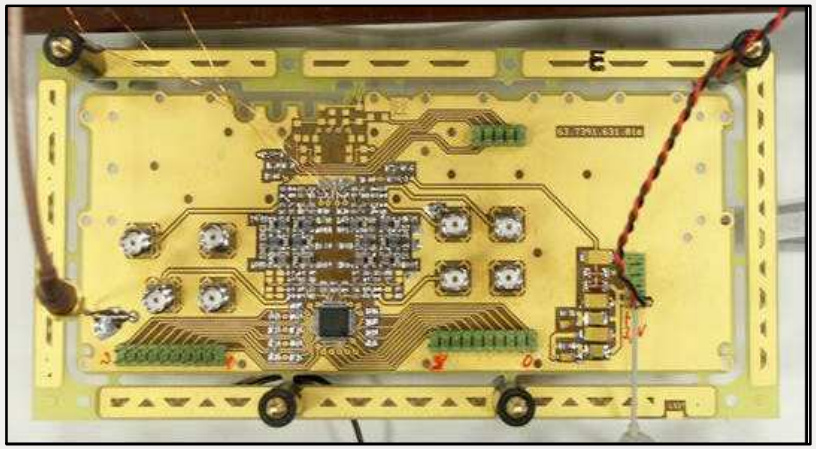
Direct X-Band TCM 8PSK Modulator - Realisation Concept



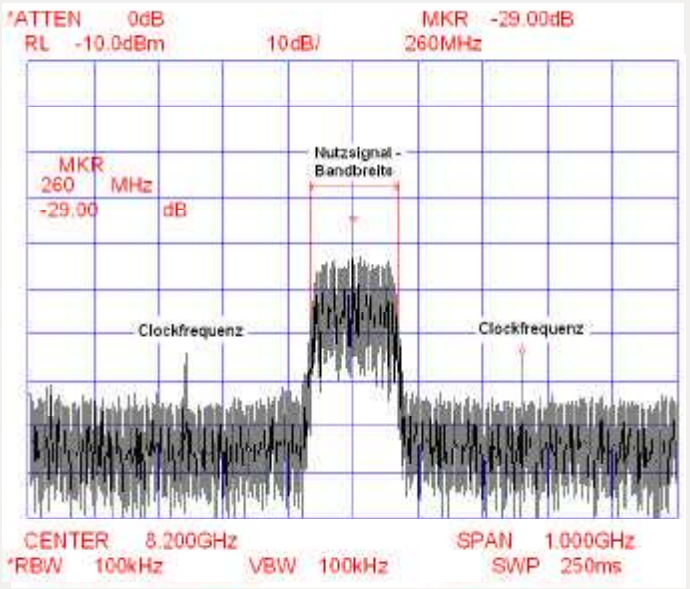
Feasibility of High Data Rate X-Band 8PSK Modulator

Based on Exisiting QPSK Modulator Design

Data Rate of 390 Mbps Demonstrated with Filtered 8PSK Using Commercial D/A-Converter



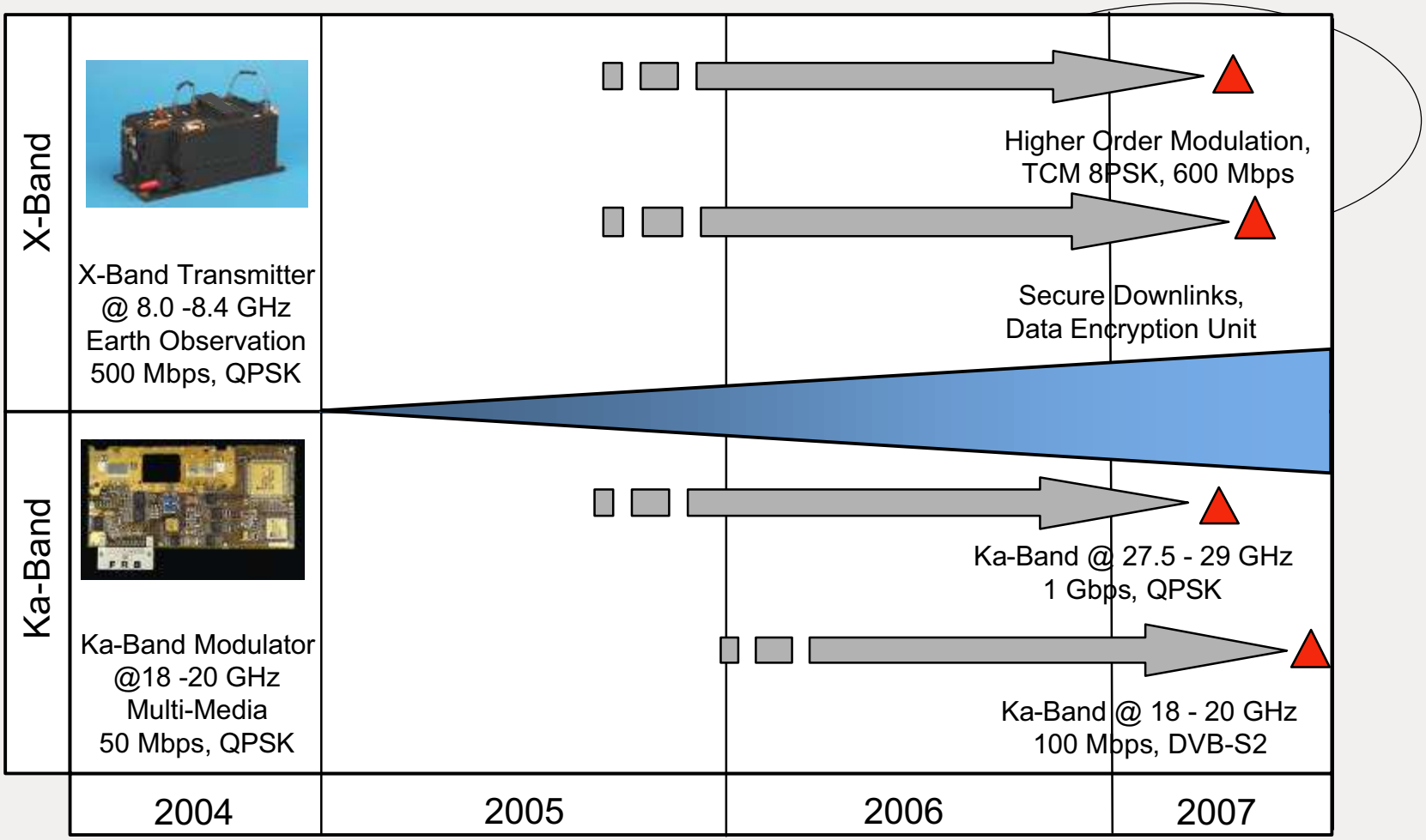
8PSK Modulator Breadboard



Data Rate for Filtered 8PSK Limited to ~ 250 Mbps due to Availabilty of Related Space Qualified Parts (DAC) and Ground Station Demodulators

For Higher Data Rates Use of Hard Keyed TCM 8PSK Recommended

Road Map for Tesat X-/Ka-Band Modulators



Conclusion

- Tesat‘s X- Band QPSK Data Transmitters Offers Advantages in Data Rate Perfornace, Flexibility, Manufacturing Costs and Schedule

- Key Figures:

Modulation Scheme	Hardkeyed QPSK
Data Rate Capability	max. 500 Mbps in X-Band
Output Power Classes	6 W, 20 W, 120 W

- Feasibility of Filtered 8PSK Modulator at 390 Mbps Demonstrated

- Data Rate for Filtered 8PSK Limited to ~ 250 Mbps due to Availabilty of Related Space Qualified Parts and Ground Station Demodulators

- Tesat‘s Roadmap Envisages Development of 8PSK Modulator and on the Long Term Expansion to Ka-Band